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RESEARCH

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Diagnostic accuracy of visual triage checklist in early recognition of COVID-19 cases in the pediatric population: A retrospective cohort study

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Abstract

Background During the coronavirus disease 2019 (COVID-19) pandemic, healthcare facilities developed surveillance systems to identify patients suspected of having COVID-19 to segregate them during their hospital stay. As a part of this infection control strategy, the Ministry of Health in the Kingdom of Saudi Arabia developed a visual triage (VT) checklist for early screening and isolation of patients in the hospital. The aim of this study was to evaluate the diagnostic accuracy of this visual triage checklist in identifying children with COVID-19.

Methods This was a retrospective, single center study that included all children who were tested for COVID-19 and were admitted to the hospital through the pediatric emergency department. The diagnostic accuracy of the visual triage checklist was assessed using COVID-19 PCR as the gold standard.

Results A total of 1333 patients were included. The visual triage checklist had a sensitivity of 94.3% (95% CI: 87.2–98.1) and a specificity of 16.0% (95% CI: 14–18) with an area under the receiver operating characteristic curve of 0.55 (0.53–0.58). The positive predictive value of the checklist was low at 7.35% (95% CI: 5.9–9.0).

Conclusion The VT checklist has high sensitivity, and is therefore potentially useful as an initial screening tool. However, the diagnosis of COVID-19 requires early secondary confirmation to avoid the large number of false positive cases associated with this tool.

Key Messages

What is already known on this topic? Healthcare institutions have developed and implemented infection control and surveillance measures during epidemics and pandemics to minimize disease transmission, protect healthcare workers and maintain essential services. One such strategy is traffic control bundling (TCB) that was developed in Taiwan in 2003 during the SARS outbreak. It was expanded upon by adding a Visual Triage checklist as a screening tool during the COVID-19 outbreak in KSA.

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What does this study add? This study analyses the diagnostic accuracy of the visual triage checklist, which was used as a screening tool during the COVID-19 pandemic in hospital settings. We report the high sensitivity of the tool, enabling rapid isolation of most positive cases.

How might this study affect research, practice or policy? VT checklist is a sensitive tool but requires inclusion in a two-tiered approach to identify individuals suspected of COVID-19. This study can serve as a basis to further develop and refine screening tools as part of infection control strategy during infectious disease outbreaks.

Keywords Infection control strategy, Pediatric, COVID-19 screening, Visual triage checklist, Diagnostic accuracy

Background

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the cause of coronavirus disease 2019 (COVID-19), was first identified in China in 2019 [1]. By January 2020 the World Health Organization (WHO) declared an international emergency [2]. Multiple public health and social measures were taken to address the pandemic globally, but within 2 years, more than 650 million confirmed cases of COVID-19 and more than 6.6 million deaths due to the virus were recorded worldwide [3]. By 2024, the total reported cases were approximately 775.9 million, of which 0.841 million were in the Kingdom of Saudi Arabia (KSA). Approximately 7 million deaths have been reported worldwide, with more than 9000 deaths in the KSA [4].

SARS-CoV-2 is a single RNA virus that causes a spectrum of symptoms ranging from coryza to multi-inflammatory organ dysfunction and death [5]. It is transmitted by droplets (person to person contact or contact with virus-infected inanimate objects), the airborne route, and the faecal and oral routes [6]. Although the majority of children are asymptomatic, fever, shortness of breath, dry cough, fatigue, dyspnea, vomiting and diarrhea are considered the most common symptoms [7]. The disease caused by SARS-CoV-2 can also lead to neurological and immunological complications, the latter of which can be fatal [8, 9].

More than 10 variants and subvariants of SARS-CoV-2 have been reported thus far [10]. The most dominant variants were the alpha variant with rates of transmissibility as high as 43–90% [11] and high mortality rates in the adult population [12, 13]. High rates of transmission, significant morbidity and mortality, and prolonged surges in demand cause further strain on already stretched resources due to hospital outbreaks [14]. During the pandemic, hospitals developed surveillance systems to isolate and cohort patients and healthcare workers suspected of having COVID-19 with early identification and isolation of suspected patients to prevent transmission within the hospital [15, 16].

One such surveillance measure is traffic control bundling (TCB), an infection control strategy that is critical in preventing in-hospital outbreaks. By isolating suspected COVID-19 patients early in their hospital visit, it helps assign an appropriate location for their assessment and management [17–20] This strategy was used in Taiwan during the 2003 severe acute respiratory syndrome (SARS) outbreak when patients at risk of infection were identified by triaging outside the hospital and were sent through guarded control routes to designated isolation areas [17]. During the Middle East respiratory syndrome coronavirus (MERS-CoV) outbreak in the KSA, the Ministry of Health (MOH) recommended assessment by visual triage (VT) checklist to identify suspected cases at hospital triage. However, an analysis of this checklist revealed that the scoring was not sensitive for MERS-CoV infection [20]. A similar VT checklist for COVID-19 was released by the MOH in KSA early during the pandemic [21, 22]. The aim of this study was to assess the diagnostic accuracy of the VT checklist in predicting COVID-19 amongst children who presented to and were admitted to the hospital.

Methodology

Study design

This was a single-center, retrospective study conducted at the emergency department (ED) of the Children's Hospital of King Saud Medical City (KSMC). The age range for children assessed in the emergency department of the Children's Hospital was from birth to the age of 12 years for boys and from birth to the age of 14 years for girls. The data collection was planned after the index and reference tests were performed. During the pandemic, the MOH in the KSA had designated centers for SARS-CoV-2 testing among suspected cases. Patients were not tested in the hospital unless admitted to an inpatient unit. The VT checklist (Fig. 1) was used to segregate patients into those requiring assessment in isolation or clean areas [21]. The VT based on the checklist was verbally performed by a nurse at a station located at the entrance of the ED before the registration point [21, 22]. Patients were given a score between 1 and 17 on the basis of presence or absence of symptoms. Patients with a score of ≥4, which served as a cut off point for segregating the patient, were isolated in a designated area where they were seen and assessed by triage nurses and doctors. PCR was performed in the ED for patients who were admitted. Information for our research was gathered retrospectively from the ED record and chart review. Data for the components of the VT checklist were extracted as completed by clinicians.

Visual Triage Checklist for Acute Respiratory Infection

Date:	Time	MRN:
Name:	ID#:	Hospital:

Circle the number reflecting the patient's condition (exposure and clinical picture) and calculate the final score:

Risks for Acute Respiratory Illnesses	**Score**	
A. Exposure Risks	***Any Patient (Adult or Pediatric)***	
A history of travel abroad in the past 14 days. **OR** A contact with a confirmed case of COVID-19 or MERS-CoV in the last 14 days prior to symptom onset. **OR** An exposure to camel or camel's products (direct or indirect*) in the last 14 days prior to symptom onset. **OR** Working in a healthcare facility.	**3**	
B. Clinical Signs and Symptoms	***Pediatric*** (≤14 years)	***Adult*** (>14 years)
1. Fever or recent history of fever.	**4**	**4**
2. Cough (new or worsening).	**4**	**4**
3. Shortness of breath (new or worsening).	**4**	**4**
4. headache, sore throat, or rhinorrhea	**1**	**1**
5. Nausea, vomiting, and/or diarrhea.	**1**	**1**
6. Chronic renal failure, CAD/heart failure, Immunocompromised patient.	**-**	**1**
Total Score		

*Patient or household member

A score ≥ 4, ask the patient to perform hand hygiene, wear a surgical mask, direct the patient through the respiratory pathway, and inform MD for assessment.

Fig. 1 Visual Triage Checklist used for COVID-19 screening as a part of traffic control bundling, to cohort patients into those requiring isolation or non-isolation areas

Demographic data were extracted from patient registration records. Patients with MIS-C were admitted both to the general ward and PICU, depending on the clinical severity of the condition.

This study was reported following the Standards for Reporting Diagnostic Accuracy (STARD) guidelines [23].

Study outcomes

The primary outcome of this study was to assess the sensitivity of the VT checklist compared with that of COVID-19 PCR test as the reference standard. The secondary outcomes were to evaluate (a) specificity, (b) negative predictive value (NPV), (c) and the positive predictive value (PPV). Furthermore, we aimed to determine the number of patients diagnosed with multisystem inflammatory syndrome in children (MIS-C) and whether they were PCR positive for COVID-19 at the time of diagnosis.

Index test

The VT checklist (Fig. 1) assesses the symptoms that the patient presents with and their risk of exposure to potential sources of infection. It assigns a score to each of the risk factors, assigning a cut off score of ≥ 4 for isolating and testing the patient for COVID-19. The reference standard was COVID-19 PCR, which was performed in the ED for all patients who screened positive and were admitted. The assessors of the VT checklist were not aware of the COVID-19 PCR results, as the PCR was performed after scoring the checklist. There was no prior assessment of the VT checklist using a derivation dataset.

Participants

A consecutive sample of all children (boys from birth up to the age of 12 years and girls from birth up to the age of 14 years) who were tested in the ED for SARS-CoV-2 via PCR between June 2020 and December 2021 were included in the study.

Patient and public involvement

Patients or the public were not involved in our research design, conduct, reporting, or dissemination plans.

Statistical analysis

Baseline characteristics were categorized and presented as counts and proportions. The differences between categories were assessed using Fisher's exact test. Receiver Operating Characteristic (ROC) analysis was employed to assess the performance of the visual triage checklist compared with the gold standard or COVID-19 PCR test. The true positive rate was plotted against the false positive rate to generate ROC curves.

The areas under the ROC (AUROC) curves were computed to provide a single measure of diagnostic accuracy. An AUROC of 0.5 indicated no discrimination, whereas an AUC of 1.0 indicated perfect discrimination. AUROC values were interpreted according to standard thresholds: < 0.5 (poor), 0.5–0.7 (acceptable), 0.7–0.9 (good), and > 0.9 (excellent). The optimal cutoff point for the diagnostic test was determined via Youden's index. Bootstrapping was used to estimate 95% confidence intervals for the AUROCs. This involved resampling the dataset with replacement and recalculating the AUROC for each bootstrap sample to assess variability.

Budirier's formula was used to estimate the required sample size for the study. To test for a minimum clinically significant sensitivity of 95%, and assuming a 6% prevalence of COVID-19 in our cohort and a width of the confidence interval of 0.05, the required sample size was 1217. We aimed to extract data on an additional 10% of the required sample size to account for missing data. Patients with missing data on the VT checklist or reference test were handled by listwise exclusion. All analyses were conducted via Stata v 18.0, College Station, TX, USA.

The study was reviewed and approved by the KSMC Institutional Review Board (Project number: H1RI-19-Aug21-01).

Results

During the study period, 1392 patients underwent PCR testing for SARS-CoV-2. The index test (VT checklist) could not be calculated for 54 patients, and there were 1338 eligible patients. A further five patients whose SARS-Cov2 PCR results were unknown were excluded, with 1333 patients included in this study. The selection of patients is illustrated in Fig. 2 and the baseline characteristics of the included patients are listed in Table 1. Most patients were infants, and the majority of presentations occurred in autumn. There were 88 (6.6%) included patients who had a positive test for SARS-CoV-2.

The components of the VT Checklist are listed in Table 2 [22]. Fever or a recent history of fever was the most common presenting complaint, whereas contact with COVID-19 was the least frequently reported risk factor.

The overall performance of the VT checklist had an AUROC of 0.59 (95% CI: 0.53–0.64) (Fig. 3). The optimal cutoff point as determined by Youden's test was 6.5, with a sensitivity at that cutoff point of 0.60 and a specificity of 0.56. At the commonly used cutoff point of ≥ 4, the VT checklist had a sensitivity of 94.3% (95% CI: 87.2–98.1) and a specificity of 16.0% (95% CI: 14–18) (Table 3). When sub-grouped by age, the performance of the VT checklist was superior for children aged > 6 years, with an AUROC of 0.70 (95%CI: 0.58–0.82).

Following a diagnosis of COVID-19, most patients were managed in the general ward, whereas 42 patients required care in high dependent unit. The diagnosis of MIS-C was more common in the setting of COVID-19 (3.5% versus 0.6%; $p = 0.046$) (Table 4).

Discussion

This study demonstrated the diagnostic accuracy of the VT checklist in identifying patients with COVID-19. While the sensitivity of the checklist was 94.3%, only a small proportion of patients had a negative index test. With a low positive predictive value (PPV) of 7.35% and a high false positive rate of 84%, the utilization of this scoring system as the sole decision to initiate isolation and prevention measures has the potential to affect the ED flow of patients, block access to inpatient beds, and lead

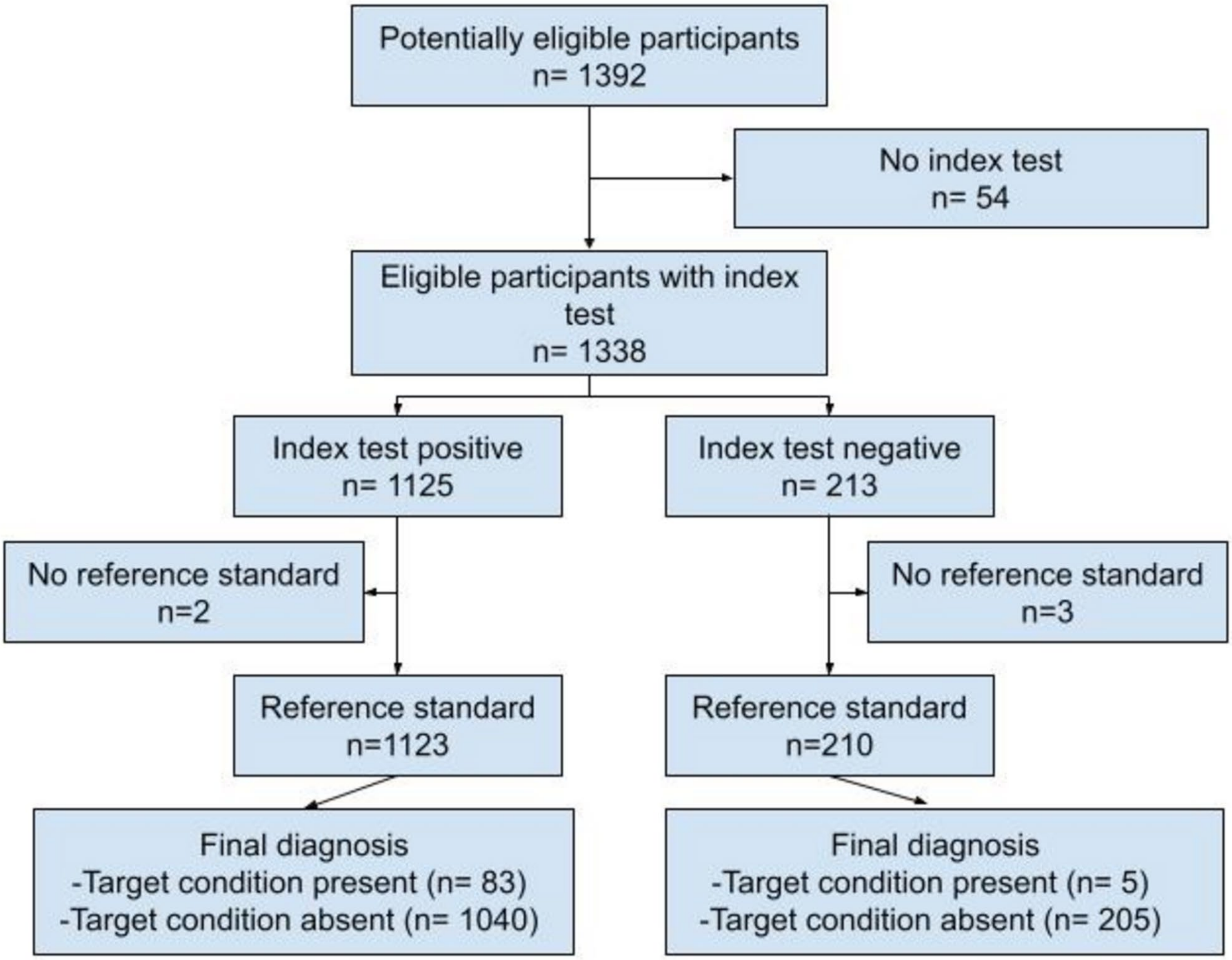

Fig. 2 STARD diagram of included participants

Table 1 Patient characteristics

Variable	Summary
Age:	
- ≤ 1 year	559 (41.8%)
- 1–6 years	464 (34.7%)
- 6–10 years	201 (15.0%)
- > 10 years	114 (8.5%)
Gender:	
- Male	760 (56.8%)
- Female	578 (43.2%)
Month of presentation:	
- March	125 (9.3%)
- April	224 (16.7%)
- May	59 (4.4%)
- June	154 (11.5%)
- July	93 (9.0%)
- August	417 (31.2%)
- September	266 (19.9%)

Table 2 Components of the visual triage checklist

Variable	*N* (%)
Recent contact with COVID-19 case	115 (8.6%)
Fever or recent history of fever	860 (64.3%)
Cough (new or worsening)	557 (41.6%)
Shortness of breath (new or worsening)	449 (33.6%)
Headache, sore throat, or rhinorrhea	225 (16.8%)
Nausea, vomiting, and/or diarrhea	543 (40.6%)
Chronic renal failure, heart failure, Immunocompromised patient*	529 (40.9%)

* Missing data for 43 patients

to the overutilization of resources. However, if patients, regardless of their COVID-19 status, are assessed in the same geographical areas of the hospital, there are potential risks of transmission of the disease. While the performance of the checklist was marginally better for children over 6 years of age, it remained sub-optimal for children younger than 6 years. Although the tool's statistical significance can be questioned on the basis of its

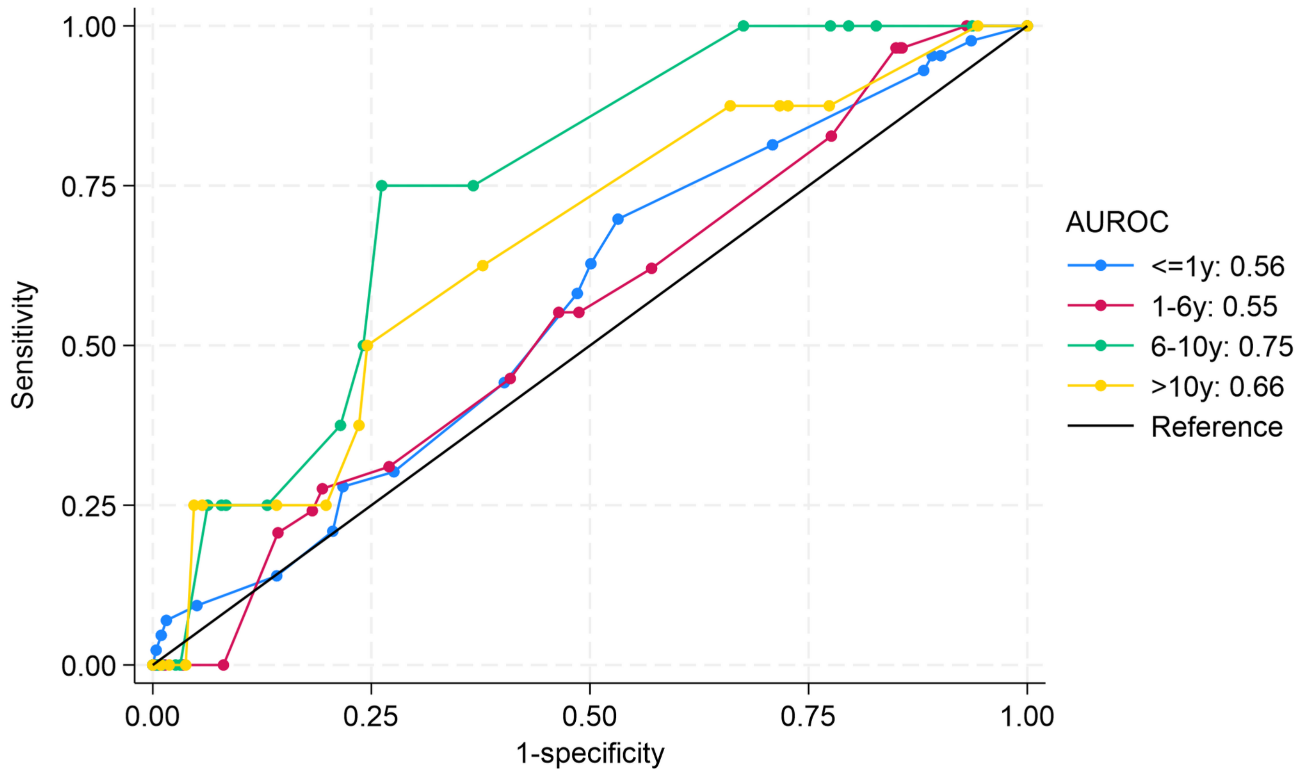

Fig. 3 Area Under the Receiver Operating Characteristic curves of the Visual Triage Checklist to predict COVID-19, sub-grouped by age groups

Table 3 Measures of diagnostic accuracy of the visual triage checklist when dichotomized to ≥4 for identifying a child with COVID-19 infection

Diagnostic Accuracy of Visual Triage Checklist	Value (95% Confidence Interval)
Sensitivity	94.3% (95%CI: 87.2–98.1)
Specificity	16.0% (95%CI: 14–18)
Positive Predictive Value	7.35% (95%CI: 5.9-9.0)
Negative Predictive Value	97.5% (95%CI: 94.4–99.2)
Positive Likelihood Ratio	1.12 (95%CI: 1.06–1.19)
Negative Likelihood Ratio	0.36 (95%CI: 0.15–0.84)
Area under the ROC Curve	0.55 (95%CI: 0.53–0.58)

ROC: Receiver Operating Characteristic

Table 4 Type of ward and diagnosis of MIS-C

	COVID-19 negative ($n = 1245$)	COVID-19 positive ($n = 88$)	*p*-value
Type of ward			0.003
- General ward	841 (67.6%)	46 (52.3%)	
- PICU	252 (20.2%)	32 (36.4%)	
- SCU	142 (11.4%)	10 (11.4%)	
- Unknown	10 (0.8%)	0	
MIS-C	7 (0.6%)	3 (3.5%)	0.046

PICU: pediatric intensive care unit; SCU: special care unit; MIS-C: multisystem inflammatory syndrome in children

low specificity, it has utility as a screening tool within the overall screening framework owing to its high sensitivity, provided that the checklist is followed by definitive testing.

During the pandemic, healthcare facilities around the world were screening patients to determine those suspected of having COVID-19 in accordance with the recommendations of the centers for disease control and prevention (CDC) [24]. This was done to as a part of an infection control strategy to: (a) prevent spread of infections from and to the community through hospitals, (b) prevent hospital outbreaks of infection. These triaging tools were based on the presence of clinical symptoms and epidemiological factors. Dadashzadeh et al. described a method of triaging patients, without assigning a score to the components of the triaging tool [25]. Their patients were segregated to isolation areas if they had fever or respiratory symptoms in the setting of a risk of exposure to COVID-19. Similarly, Zhang N et al. described a triaging tool that assigned scores to the epidemiological risk factors such as a history of travel to high-risk areas, etc. if the patient had clinical symptoms [26]. Based on the scores, they categorized the patients into high, medium and low risk for COVID-19 infection and managed them according to their protocol. An adaptation to the triage algorithm to incorporate risks of infection with COVID-19 and subsequent recommendations for personal protective equipment usage was described by Wallace et al., but it did not recommend assessing patients in segregated or isolation areas [27]. The VT checklist developed by the ministry of health in Saudi Arabia provides a structured method of assessment based on comprehensive clinical and epidemiological criteria, assigning a score to each of these, with a cut off at a score of 4 or more for segregating a patient for COVID-19 testing [22].

Though multiple screening tools were developed during the pandemic, there is a paucity of studies evaluating their diagnostic accuracy, especially in children [20, 28]. The diagnostic accuracy of the VT checklist for MERS CoV infection used in the KSA was evaluated by Alfaraj et al. in 2018, in a retrospective study and reported that the sensitivity and specificity were 74.1% and 18.6% respectively [20]. The reported 26% false negative rate allows a large margin of undetected cases, leading to a high risk of transmission. The lower sensitivity could be attributed to the fact that the MERS CoV checklist assigns a low score of 2 to fever and other respiratory symptoms, though assigning higher scores increases the over-triage rates of patients. Asayed et al. examined the diagnostic accuracy of the VT checklist for COVID-19 in adult patients, and reported a 27% sensitivity and 75% specificity [28].

The VT checklist for COVID-19 assigned higher scores to respiratory symptoms, fever, and the variables of the risk of exposure to COVID-19 patients (Fig. 1). The high false positive rate was likely due to the nonspecific nature of respiratory symptoms that had high scores such as fever, cough and shortness of breath. For example, the utility of fever for screening of COVID-19 has been previously noted to be negligible [29]. This rate of false positives leads to overutilization of resources within the hospital, increasing ED length of stay, contributing to ED overcrowding and access blocking inpatient isolation and quarantine beds, in addition to having a negative psychological impact on patients and their caregivers [30]. However, as a part of the traffic control bundling (TCB) strategy, patients need to be isolated at the point of entry on the basis of symptoms that could be indicative of COVID-19 [19]. This infection control strategy is essential for preventing in-hospital outbreaks of infection and breaking the community-hospital-community transmission cycle.

The low specificity of 16% and a low PPV of 7.39% allows for a large false positive rate and leads to a higher than acceptable rates of over triaging. However, with a high sensitivity of 94.3%, and a NPV of 97.6% the VT checklist ensures that very few cases are undetected. This makes it valuable in a high risk setting such as that of a hospital's ED or OPD, where early detection and isolation is crucial and the consequences of missing a case can be catastrophic. The VT checklist can be an effective first step in a two-tiered screening approach, allowing individuals identified by this tool to undergo further testing via rapid and affordable molecular tests in ED. This can enhance the specificity of the screening tool. Reverse transcription polymerase chain reaction (RT-PCR) testing remains the gold standard of testing but cannot be used in the ED setting where rapid decision-making is required. Immunoassays like Lateral Flow Tests (LFT) or Enzyme Linked Immunosorbent Assay (ELISA) are affordable, can produce results within minutes but have lower sensitivities [31, 32]. More recent molecular tests such as RT-LAMP (Reverse Transcription Loop-mediated isothermal amplification) and CRISPR (clustered regularly interspaced short palindromic repeats) based techniques are rapid, producing results in less than one hour, and have high sensitivities of 95.5% and 100% respectively [33, 34]. These tests can be used as a second step of the screening process, allowing more economical use of resources.

This study identified only 9 children with MIS-C, who were diagnosed on the basis of their clinical and laboratory findings, excluding COVID-19 serology testing, which was not available at our center. MIS-C has been described to occur, on average, one month after the initial COVID-19 infection, with negative PCR results but positive serology and other markers of diagnosis [35]. These results are similar to reported rates of "Kawasaki-like disease" or MISC from other studies, but contrary to our results [36].

The most common symptoms in the cohort of children with suspected COVID-19 were fever (77.27%), cough (44.31%), gastrointestinal symptoms (42.05%) and shortness of breath (34.09%). A similar frequency of fever was shown in studies conducted by Alnajjar et al. and Alshengeti et al. in the KSA, although the frequencies of respiratory and GI symptoms were much lower [37, 38]. The results of these studies were similar to those of a retrospective study conducted in Italy by Filippo et al., who reported a high frequency of fever but lower frequencies of other system involvement [39]. These studies may have been subject to cognitive bias due to the small sample sizes. A multicenter retrospective cohort study with a larger sample size of 567 children conducted by AlGhamdi et al. demonstrated that 81.8% of their cohort presented with symptoms of fever, cough and shortness of breath [36].

This study enrolled a relatively large population and achieved the required sample size. The study is also limited in its generalizability because it is a single center, retrospective study and includes only children under the age of 14 years and those who were admitted to hospital. The diagnostic accuracy could be different in adults given the greater prevalence of COVID-19 in adults compared to children. Only a few patients with a score of less than 4 were included in the study because of limited testing in this cohort of patients in the in-hospital setting. Repeating the study with PCR in all patients who presented to the ED, rather than those who were admitted only, may therefore provide better measures of the diagnostic accuracy of the VT checklist.

Conclusions

Screening for COVID-19 in the hospital setting remains essential from the perspective of infection control measures, to prevent hospital outbreaks and community transmission. The performance of the VT checklist was suboptimal for use as the only screening tool. However, with the high sensitivity, it can serve as a valuable and effective tool for the early detection and isolation of patients suspected of having COVID-19 via a two-tiered screening approach. Further research to evaluate the diagnostic accuracy of the VT checklist in conjunction with rapid diagnostic tests is recommended.

Abbreviation

AUROC	Area Under the Receiver Operating Characteristic
COVID-19	Coronavirus Disease – 2019
ED	Emergency Department
KSA	Kingdom of Saudi Arabia
KSMC	King Saud Medical City
MERS-CoV	Middle East respiratory syndrome coronavirus
MIS-C	Multisystem Inflammatory Syndrome in Children
MOH	Ministry of Health
NPV	Negative Predictive Value
PPV	Positive Predictive Value
PCR	Polymerase chain reaction
RNA	Ribonucleic Acid
ROC	Receiver Operating Characteristic
SARS	Severe Acute Respiratory Syndrome
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
STARD	Standards for Reporting Diagnostic Accuracy
TCB	Traffic Control Bundling
VT	Visual triage
WHO	World Health Organization

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Author contributions
L.A, Ah.A, Ab.A. made substantial contributions to the conception and design of work; H.P., W.A., M.A., R.S., A.I. made contributions to the data acquisition and analysis; B.M. made significant contributions to the data analysis and interpretation; A.I, B.M., Ab.A., drafted the manuscript and revised it; all authors approved the submitted version of the manuscript and agreed to be personally accountable for their own contributions and agreed to ensure that questions related to any part of the work are appropriately investigated, resolved and the resolution documented in the literature.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was reviewed and approved by the institutional review board (IRB) of KSMC (project number: H1RI-19-Aug21-01). The study was a retrospective chart review, and the need for obtaining consent was waived by the IRB. Official permission was requested to gain access to the data, with the privacy and confidentiality of the data and study results secured by restricting unauthorized access. This study was carried out in compliance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

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